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The use of remote sensing technology in defining the water depth in the lakes and water bodies: Western Iraq as a case study

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The study's primary purpose is to explore an appropriate way of monitoring and assessing water depths using the satellite remote sensing technique of the Al Habbaniyah Lake in Iraq. This research studied the experience-conditions (thresholds) of different bands for multi-temporal satellite image data with different satellite image sensors (Landsat 5-TM, and EO1-ALI) for the same region, to recognize regions of water depths. The threshold values are taken that to separate the Al Habbaniyah Lake to the required depths (shallow, deep, and very deep), as a supervised method. A three-dimension feature space plot had used to represent these regions. The relationship of the mean values of the three separated water regions with all TM and ALI bands is studied. Other lakes in Iraq were used to actualize the validity and accuracy of this technique to find the water depth regions; Al Qadisiyha and Al Mosul lakes are in the West and North of Iraq of Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Landsat-5 Thematic Mapper (TM) satellite images respectively. This technique succeeded in determining Al Habbaniyah lake depths but failed to recognize the regions of water depths for some of the lakes which have the big depths by correct form such as; Al Qadisiyha and Al Mosul lakes.
Keywords: Water detection, experience-conditions, remote sensing,eo1-ali.

INTRODUCTION

Most of a water manager's time is taken up dealing with daily to interannual fluctuations in the water supply. Investment in in-situ monitoring is critical in determining how well-prepared we are to cope with this unpredictability. This is significantly associated with a country's economic development level (Howard & Lacasse, 2004).Water bodies (rivers, lakes, and seas) may be quickly moving (during floods, tides, and storm surges), making it challenging to gather accurate distribution and variation information using typical ground survey approaches. As more high-resolution satellite photos become available, both in terms of spatial and spectral detail (Abduljabbar, *et al.*, 2020), the fast advancement of remote sensing technology, improvements in tools for geographic data analysis (GIS platforms) (Abdul-Hameed and Hatem, 2021), and progress in image processing techniques have made collecting this information from satellite pictures a practical reality in the present day. (Richards, 2013), the solution that is both economical and effective. These findings are supported by other research (Wang, 2003; Smith, 1997). A few benefits of satellite-based remote sensing are: It is 1) easy to do and 2) frequent enough to cover much terrain in photos. Thirdly, the cost per square kilometer is often less than that of on-site surveying and tracking (Al-alaf & Rasheed, 2017; Naji & Hatem, 2013)
We rely heavily on the water as a resource. Many aspects of this resource's quality, quantity, and geographic distribution may be tracked with visual picture interpretation. (Hussein & Al-Obaidi, 2013). Most of the sunlight penetrating a transparent body of water is typically absorbed within a few meters of the surface. Absorption strength is very wavelength dependant. Infrared light is absorbed by water down to a depth of only a few tenths of a meter; therefore, even shallow bodies of water seem quite black in infrared photographs. Light with a wavelength between (0.48 and 0.60) μm penetrates clear water the best, allowing for imaging of bottom features. Even while blue light travels deep, it is widely distributed, creating a haze or "underwater" appearance. Red light travels just a short distance and is not helpful for outdoor use (Al-Hamadan, 2009; Lillesand, *et al.,* 2015).

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The accuracy constraints of water color remote sensing inversion mean it is best used for monitoring aquatic environments. Several water body extraction methods have been developed and used in recent years using the spectral properties of this area. All the significant water pixels can be found using these methods. But they rely heavily on knowledgeable humans to choose good cutoff values (Egorov *et al.,* 2019).

The near and medium infrared area of the electromagnetic spectrum (0.7–2.5) μm was the best region for distinguishing between water and land through histogram analysis of the data from various bands (Lilles *et al.,* 2015). In this area, water surfaces absorb almost all incoming radiant flux, whereas land surfaces (usually made up of flora and bare soil) reflect a significant quantity of near and middle infrared light. The detection of water bodies is enhanced when near and middle-infrared wavelengths are used together (Abboud, 1998).

One of the algorithms used the threshold values of NIR & SWIR Bands respectively by the rule-based method, which recognizes water regions (water bodies) if the pixel value satisfies the rule; Band 4<45, and Band 5<36 (Naji & Tawfeeq, 2011; Abduljabbar & Naji, 2020).

For Al Habbaniyah lake, researchers provided a method that uses Landsat-5 TM and EO1-ALI satellite data to determine water depths to three levels (shallow, deep, and very deep) with the help of experience conditions. These layers were represented using spectrum signature curves and three-dimensional feature space plots.

MATERIALS AND METHODS

The present research was conducted to determine the water depths of some Iraq Lakes. This research has been performed and built using ArcGIS 10.8, ENVI 5.6 softwares, and MATLAB R2020a language. Materials and methods in this work include two parts, which are as follows:

***Regions of Interest and Available Data*:** Al Habbaniyah, Al Qadisiya, and Al Mosul lakes lie in Al Anbar and Ninive governorates. Map location of these interest regions had shown in Fig.1. The samples of satellite images for Al Habbaniyah lake were used to illustrate the implementing this technique, as shown in Figures (2a & 2b). They extend between latitudes (33°25'36.23") to (33°11'47.20") north between longitudes (43°17'4.94") to (43°35'32.95") east, and latitudes (33°25'25.26") to (33°11'32.52") north between longitudes (43°17'15.09") to (43°35'44.19") east for the multi-temporal scenes with different sensor Thematic Mapper (TM) which was taken on 4 of March 1990 onboard Landsat-5 satellite, and Advanced Land Imager (ALI) which was taken on 16 of March 2003 onboard the Earth Observer-1 (EO-1) satellite, respectively. The total area of both temporally viewed sets of scenes was (739.56) km^2. These temporal scenes were geometrically corrected and previewed, then followed by smaller size extracted (916 × 994) pixels with three bands combination (SWIR, NIR, and Red) (Abdul-Hameed and Hatem, 2022). Hydrogeological, Al Habbaniyah lake water depth ranges from (>1) m, (11-9) m, and (17) m in the surroundings, the middle, and at the end of the lake, respectively, for the mentioned years, as field measurements. Al Qadisiya lake lies on the Euphrates river, 8 km north of Haditha city, west of Iraq, with latitudes (34º26'6.74") to (34º7'35.03") northing and longitudes (42º1'37.68") to (42º34'5.10") easting, as shown in Figure 2-c. It covers (1573.47) km^2. The interesting data source was the Enhanced thematic mapper Plus (ETM+) image onboard Landsat-7 satellite, with three bands combination (SWIR, NIR, and Red). Al Qadisiya lake water depth ranged (138 m), as a field measurement in 2002.

Al Mosul lake is located on the Tigris river in Mosul city center north of Iraq; geographic coordinates latitude (36º56'1.30") to (36º34'23.96") N, longitude (42º27'9.28") to (43º4'13.82") E, Figure 2-d. The available data was a thematic mapper (TM) image. It covers a ground area of around (2713.42) km^2 with three bands combination (SWIR, NIR, and Red)Al Mosul lake water depth range (318m) in 1992 year, as a field measurement (LEGOS., 2010). All available remotely sensed data were used in this research as listed in Table 1, were downloaded from the United States USGS's center for Earth recourses, Observation, and Science. (Survery, 2020).

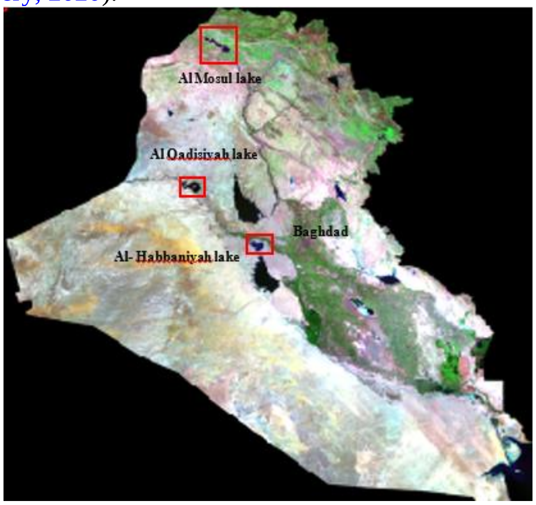


Figure 1. Location Map of the Study Regions (Al Habbaniyah, Al Qadisiyah, & Al Mosul lakes) in Al Ramadi, Haditah, & Al Mosul Cities (USGS, 2020).

***Research Methodological*:** The work procedures can be described as follow:

1. To detection and separation of water body for Al Habbaniyah lake with different depths, the following experience-conditions (thresholds (TH)) technique had

Table 1. Information on the available satellite scenes.

Lake	Satellite scene	Spatial Resolution (m)	Date
Al Habbaniyah	Landsat-5 (TM)	30	4 March 1990
Al Habbaniyah	Earth Observer-1 (EO-1)	30	16 March 2003
Al Qadisiya	Landsat-7 (ETM+)	30	20 November 2002
Al Mosul	Landsat-5 (TM)	30	4 October 1992

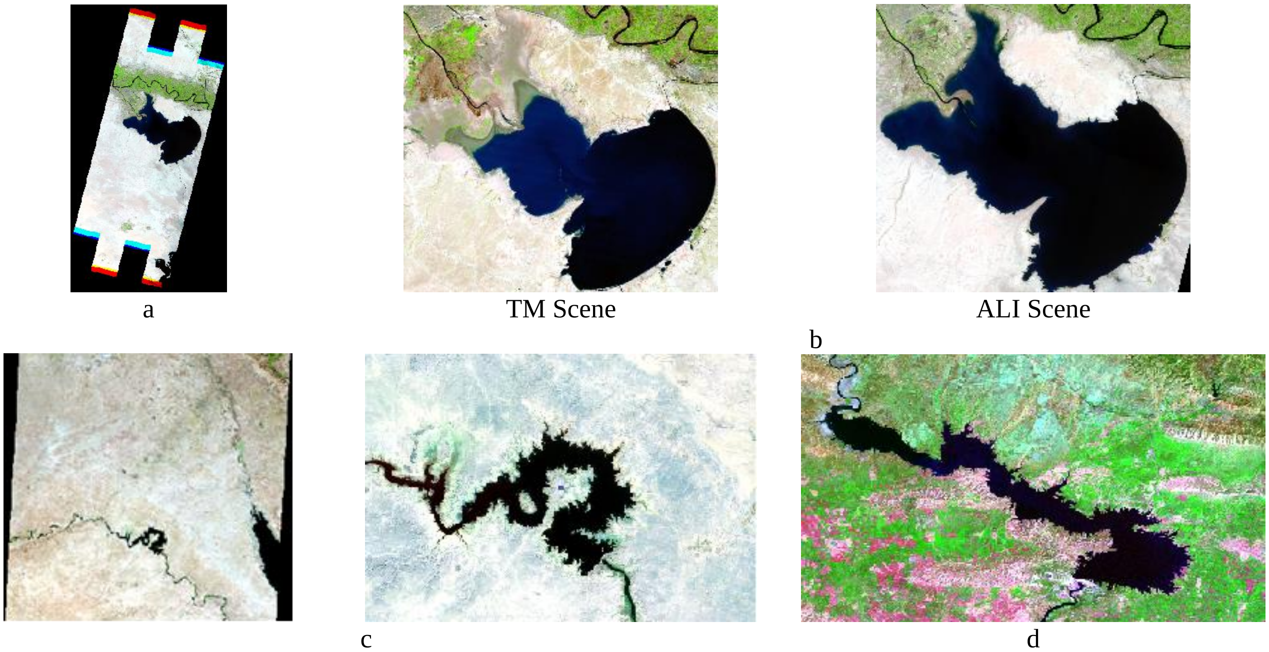


Figure 2. a- EO-1, ALI (RED, NIR, & MIR) Spectral Images, in 2003 West of Iraq (Size 1831 × 3461 Pixels) (USGS, 2020) , b-Muilt-Temporal Al- Habbaniyah lake for Landsat TM & Geo-Corrected EO-1 ALI, in Years 1990, and 2003 (Each of Size 994 × 916 Pixels), c- RGB Color Composite of Landsat 7, ETM+ bands 5, 4 and 3, in 2001 West of Iraq (Size 6514 x 6000 Pixels), and Tested Scene of Al Qadisiya lake (Size 1632 × 1187 Pixels), d- Tested Scene of Al Mosul lake (Size 2393 x 1396 Pixels) in 1992 North of Iraq

written based on bands (Naji & Hatem, 2013); TM3, TM4, and TM5, with band combination of 5, 4, and 3 for thematic mapper (TM) data, and ALI_5, ALI_6, and ALI_9, with band combination of 9, 6, and 5 for ALI data as RGB, such that:

i. Region of shallow water had delineated with the conditions:

$TH1 \leq 36$ and $13 \leq TH2 \leq 79$,……..(1)

ii. Region of deep water had delineated with the conditions:

$TH2 < 14$ and $22 \leq TH3 \leq 71$, …….(2)

iii. Region of very deep water had delineated with the conditions:

$TH2 \leq 11$ and $TH3 < 22$,…………..(3)

Where: TH1: is represents the specific threshold value of band 5 for TM data and band 9 for ALI data (MIR-Infrared band).
TH2: is represents the specific threshold value of band 4 for TM data and band 6 for ALI data (NIR-Infrared band).
TH3: is represents the specific threshold value of band 3 for TM data and band 5 for ALI data (RED band).

2. Calculate the mean of digital number (DN) value for each spectral band of the TM have (7 spectral bands), and ALI have (10 spectral bands) scenes, for each water depth classes.
3. Draw the spectral signature curve for each depth (class) according to the results in step 2.
4. Implement the previous steps on other lakes in Iraq with different water depth regions to approve the validity and accuracy of these experience-conditions to find the water depth regions for Al Razazah, and Al Qadisiyha lakes scenes.

RESULTS AND DISCUSSION

After the correction and matching procedure, a strategy based on experience and previous data was used to multi-temporal scenes captured by a range of satellite sensors (including Landsat TM and EO-1 ALI). Using the first order (linear) of a polynomial function and cubic convolution registration

resampling, these sceneries have been geometrically rectified in the World Geodetic System 1984 datum "WGS84," and the Universal Transverse Mercator projection (zone 38 north) "UTM N38." We found that the image-to-map registration had an RMS inaccuracy of between 0.07 and 0.96 pixels. Table 2 shows that a total of 6 GCPs were employed to calibrate the ALI scenario.

The false color picture, including RGB values of TM5, TM4, and TM3 and the ALI values of 9, 6, and 5, correctly extracts the water body information (RGB). Since they create visual contrast, these color schemes have low correlation

Table 2. Al Habbaniyah lake Registration Parameters .

Total (RMS) error = 0.58 m							
GCP No.	**Base TM Scene, 1990**		**Warp ALI Scene, 2003**		**Error (meter)**		**RMS error (meter)**
	X	**Y**	**X'**	**Y'**	**X**	**Y**	
1	835.00	117.25	2484.00	426.00	0.41	-0.40	0.57
2	906.00	721.00	2687.00	2146.00	-0.02	0.07	0.07
3	370.00	902.00	1162.00	2663.00	0.14	-0.28	0.31
4	112.00	73.00	427.00	299.00	0.28	-0.59	0.66
5	174.25	270.25	605.00	860.25	-0.41	0.86	0.96
6	847.00	174.00	2519.00	587.00	-0.40	0.34	0.52

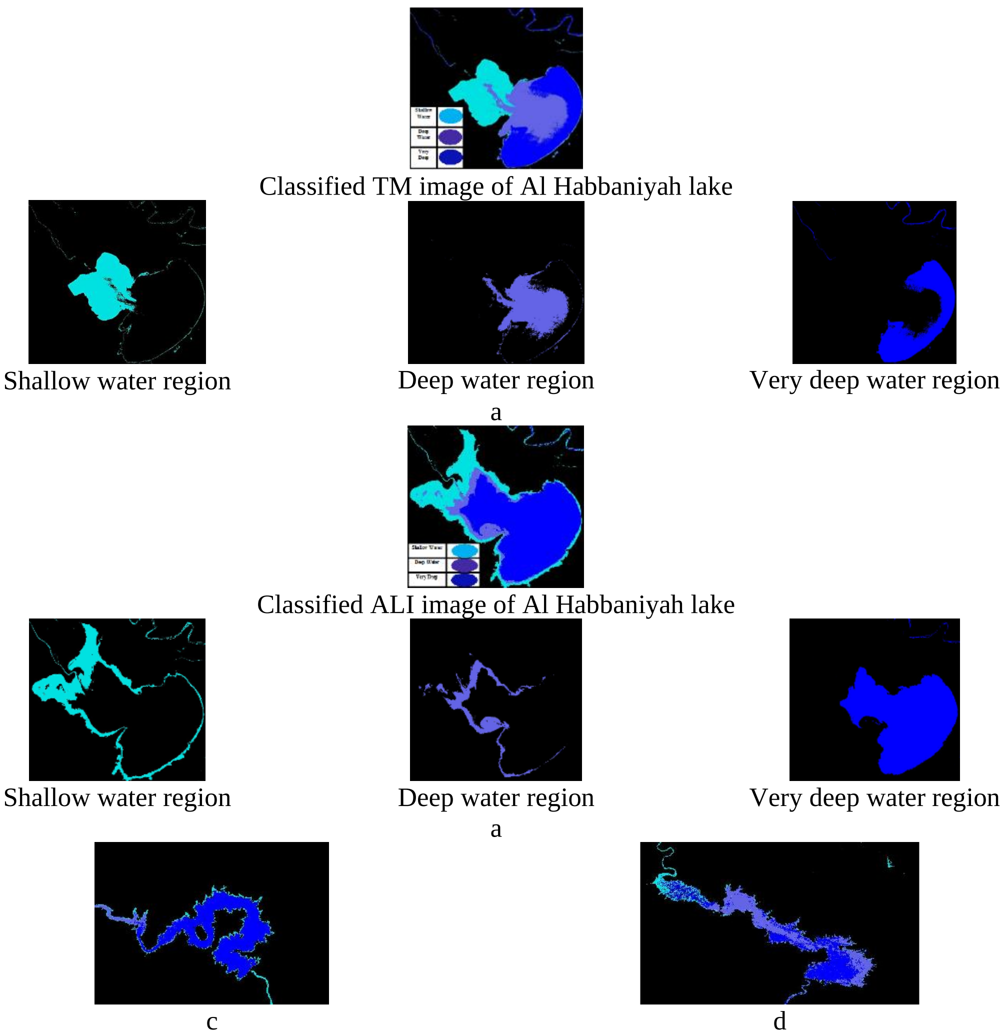


Figure 3. a & b Classified TM & ALI Images of Al- Habbaniyah lake, c- Classified ETM+ Image of Al Qadisiya lake, d- Classified ETM+ Image of Al Mosul lake and They Water Depth Regions.

coefficients and, as a result, convey more information than other color mixtures. They accurately portray the sea and land interaction and have a color scheme strikingly close to the real Earth.

Figure (3a & 3b) shows how the spectral characteristic of water absorption at various depths in Al Habbaniyah lake was utilized in conjunction with the experience-conditions approach to determine the various depths of the lake. Equations 1, 2, and 3 provide the threshold values that have been determined to be extremely suitable for use with these experience conditions. Previous equations of experience conditions were used to classify Al-Qadisiya and Al Mosul lakes (Figure 3(c, d)).

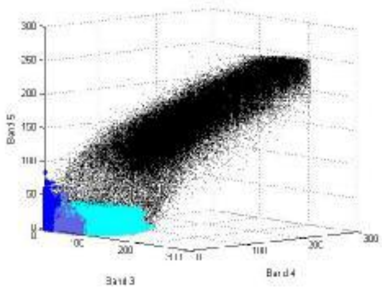
It was easier to explain the water depth zones shown in Figure 4 in a three-dimensional feature space plot since their detection depends on three bands, as was described before. This feature space map shows the amounts of pixels representing water depth areas as a function of intensity. The average values were used to build the spectral signature curves of the water depth areas, as shown in Figure 5. The values for these depth regions to each band are presented in Tables 3 and 4. The mean is one of the main spectral signature statistics that helps differentiate across groups. Since satellite imagery, when used correctly, will provide some clear information on areas without resorting to fieldwork (which is impossible in some places), this property of matter makes it

Table 3. Mean Pixel Values for Al Habbaniyah Lake Water Depth Regions Versus TM Bands

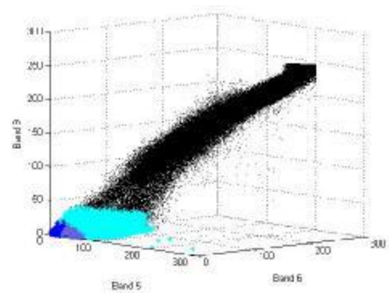
Bands / ***Regions***	1	2	3	4	5	6	7
Shallow Water	98	103	80	23	5	20	7
Deep Water	95	82	36	7	4	13	6
Very Deep Water	72	52	10	4	4	14	6

Table 4. Mean Pixel Values for Al Habbaniyah Lake Water Depth Regions Versus ALI Bands

Bands / ***Regions***	1	2	3	4	5	6	7	8	9	10
Shallow Water	65	75	109	81	57	19	16	14	12	12
Deep Water	50	56	59	54	32	11	6	6	6	5
Very Deep Water	20	25	24	12	12	10	10	10	10	7

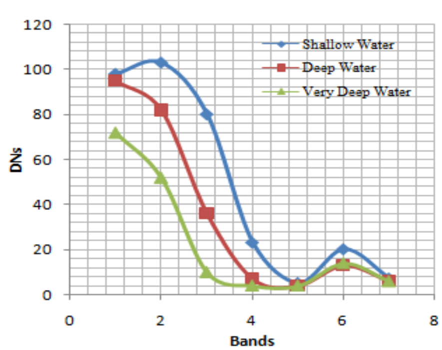


TM scene

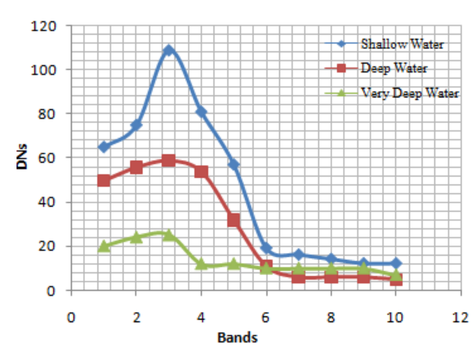


ALI scene

Figure 4. **3-D Feature space plot of the water depth regions for TM and ALI scenes**



TM Scene



ALI Scene

Figure 5. Spectrum Signature Curves of the Water Depth Regions for TM & ALI Scenes

possible to identify other different depth regions (classes) and separate between them.

***Conclusions*:** This work presents an effective technique to recognize different water depths of an Al Habbaniyah lake with a fast performance from remote sensing data without returning to the field studies for the area that can not be reached by using simple conditions. This technique can be implemented on fewer depths, such as Al Habbaniyah lake. Where this technique failed to recognize the regions of water depths for some of the lakes which have the big depths by correct form such as; Al Qadisiyha and Al Mosul lakes, due to the sunlight penetration for the surface of water body about from 2 m to maximum 20 m, as shown in Figure 3.

The behavior of water depth regions as illustrated in the spectrum signature curve in figure 5, had relatively low gray tones since water absorbs most of the incident solar irradiation, but it had high reflectance in blue for TM scene since bluish objects and areas generally show this band as lighter gray tones than others. However, the shallow water region had different behavior; its blue band for TM scene reflectance is less than the green band for this scene, and band 3 for ALL scene in the visible region, indicating aquatic plants' existence. The amount of chlorophyll in the water affects how reflective it is. Increases in chlorophyll content often reduce water's reflectivity in blue wavelengths while increasing it in green. A water body's depth and kind may be determined by comparing its surface and bottom reflections.

Thermal IR Band for the TM scene produces an emitted radiation image; in general, light tones mean higher temperatures, which give the interpretation of water depth regions' behavior. The deeper water region is affected by surrounding soil less than others did; therefore, its temperature is greater. Shallow water regions had different behavior; their temperature is greater than others due to aquatic plants. However, there are several limitations to this technique; for example, the misdetection may occur from aquatic plants affecting water region reflectance and determinde the water bodies depths correctly. The research results are more conformable to the fact because it was depended on field measurements, which are mentioned in the (regions of interest and available data) paragraph, and was accredited in Al Habbaniyah lake studying.

Al Habbaniyah Lake can be calculated after the river body was extracted from the scene using image processing methods.

***Authors' contributions*:** T.A.H Naji, designed, completed the experiments; S.A.Q. Abdul-Hameed, D.A.Q. Abdul-Hameed prepared the draft and reviewed and finalized the draft.

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Ethical statement: This article does not contain any studies regarding human or Animal.

***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere**.**

***Code Availability*:** Not applicable.

Consent to participate: All authors participated in this research study.

***Consent for publication*:** All authors submitted consent to publish this research.

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